

XIV. Dar al Gani 476 (ver. 2003)

Basalt, 7 fragments, 6 + kg.

Apparent strewn field (*with more to be found!*)

Introduction

DaG 476 was found on May 1, 1998 in the Dar al Gani region of the Libyan Sahara (Zipfel *et al.* 2000) and weighs 2015 grams (figure XIV-1). A second large fragment, **DaG 489** (2146 g) was also found in 1997 or 1998 (Folco *et al.* 2000). The region is located 27°N - 16°E, between the cities of Zillah, Sabha and Tmassah (Schluter *et al.* 2002). A third fragment, DaG 670 (1619 g) was found in 1999 (Folco and Franchi 2000). It was found broken in three pieces (688 g, 610 g and 321 g). Two smaller fragments DaG 735 and DaG 876 were reported from the same region by Bartoschewitz and Ackermann (2001). Thus, this region appears to be a 'strewn field', where more fragments of the same fall might be recovered. The surfaces of these fragments have no fusion crust, and some sides have brown desert varnish. Some fractures contain calcite due to desert weathering.

Petrography

Dar al Gani 476 (and its paired companions) is a basaltic shergottite composed of olivine megacrysts up to 5 mm set in a fine-grained groundmass of pyroxene, maskelynitized plagioclase and mesostasis. The modal mineralogy of DaG 476 is about 60% pyroxene, 15% olivine, 15% feldspathic glass, 3% opaques, 5% 'impact melt pockets', and with 1-2% carbonate. Minor phases reported include chromite, ilmenite, whitlockite, Clapatite, pyrrhotite with Ni-rich exsolutions and perhaps "iddingsite".

Brief descriptions of the bulk hand specimens can be found in Folco *et al.* (2000) and Mikouchi *et al.* (2001).

The seven fragments of DaG are similar to one another as well as to SaU and to EETA79001, lithology A (Wadhwa *et al.* 2001). The olivine/pyroxene 'megacrysts' within these melts are also similar. Wadhwa *et al.* (2001) and others make the case that the megacrysts may not be true xenocrysts.

According to Herd *et al.* (2002), DaG 476 crystallized at relatively high oxygen fugacity (QFM).

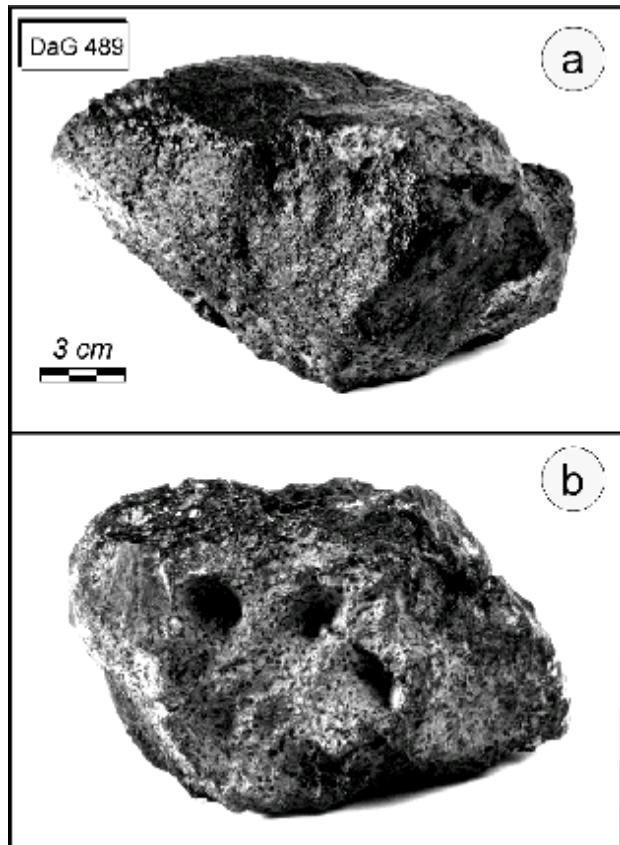


Figure XIV-1: Photographs of Dar al Gani 489 kindly provided by Luigi Folco (see Folco *et al* 2000). (a) DaG 489 is devoid of fusion crust, but has a dark brown film of desert varnish. (b) surface once buried in sand showing porphyritic texture. The cm-sized hollows are wind-carved remnants of regmaglypts.

Mineral Chemistry

Olivine: Olivine is typically present as large subhedral crystals, sometimes embayed by the groundmass minerals, suggesting reaction with the groundmass magma (Mikouchi *et al.* 2001). The composition is zoned from Fo_{76} (core) to Fo_{58} (rim). MnO is correlated with FeO and zoned from 0.4 to 0.8% ($\text{FeO/MnO} = 50$.) Folco *et al.* (2000) report Fo_{80} for DaG 489. Mikouchi *et al.* (2001) have also studied Ca, Cr and Ni contents of olivines in DaG and Herd *et al.* (2000, 2001) have analyzed for Ni, Co, Mn, Sc, V, Cr and Ti by ion microprobe.

Mineralogical Mode

	Zipfel <i>et al.</i> (2000)	Mikouchi <i>et al.</i> (2001)	Folco <i>et al.</i> (2000)	Wadhwa <i>et al.</i> (2001)
Olivine	14	17	24	10.4
Pyroxene	58	60	59	64.6
Plagioclase glass	17	14	12	14.4
Opaques	3.8	2.6	2	1
Phosphate	tr		1	1
Impact melt glass	4.5	4.0		7.2
Carbonate	2.7	2.2		1
			1	3.1

Pyroxene: Low-Ca pyroxene is zoned from $\text{En}_{76}\text{Fs}_{21}\text{Wo}_3$ to $\text{En}_{58}\text{Fs}_{30}\text{Wo}_{12}$. Augite is $\text{En}_{50}\text{Fs}_{18}\text{Wo}_{32}$ (figure XIV-2). Some low-Ca pyroxene (orthopyroxene?) is relatively Mg-rich (Folco *et al.* 2000; Mikouchi *et al.* 2001). REE abundances of orthopyroxene megacrysts are consistent with their origin as xenocrysts rather than as phenocrysts (Wadhwa *et al.* 2001).

Feldspar: Plagioclase glass (maskelynite) is An_{70-50} (most An_{60+}).

Phosphate: Merrillite is homogeneous $\text{Ca}_{8.85}(\text{Mg},\text{Fe})_{1.05}\text{Na}_{0.27}(\text{PO}_4)_7$ (trace F = 0.6%). Merrillite has been analyzed for REE by Wadhwa *et al.* (2001).

Opaques: Euhedral chromite, Ti-chromite and rare ilmenite are found and have been analyzed by Wadhwa *et al.* (2001) and Herd *et al.* (2002).

Carbonates: Nearly pure calcite is reported by Mikouchi *et al.* (2001).

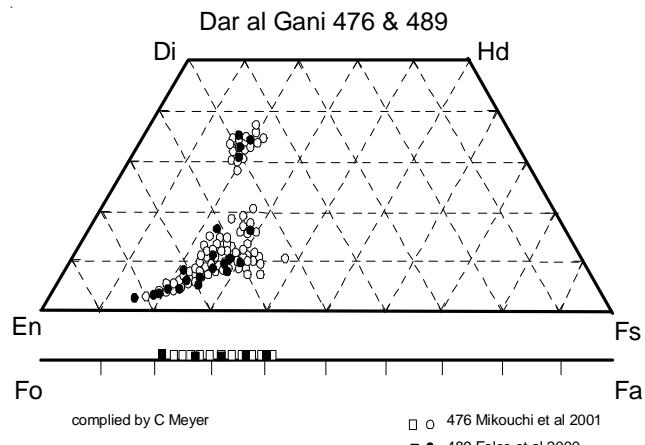


Figure XIV-2: Pyroxene and olivine composition diagram for Dar al Gani 476 and 489 (data replotted from Mikouchi *et al.* 2001 and Folco *et al.* 2000).

Iddingsite: Greshake and Stoffler (1999) and Mikouchi *et al.* (2001) report trace “iddingsite” on the rims of some of the olivine grains.

Whole-rock Composition

Zipfel *et al.* (2000), Folco *et al.* (2000) and Barrat *et al.* (2001) have determined the chemical composition (Table XIV-1). DaG 476 is ultramafic (high mg*) and light-rare-earth-element depleted (figure XIV-3). DaG 476 is also depleted in Rb, Nb, Cs, Ta and Th (figure XIV-4). Chemically, DaG 476 is more like lherzolitic shergottites than basaltic shergottites.

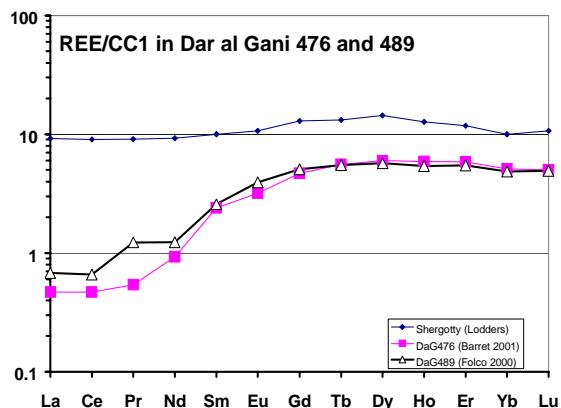


Figure XIV-3: Normalized rare earth element diagram for Dar al Gani 476, 489 and Shergotty (data replotted from Folco *et al.* 2000, Barret *et al.* 2001 and Lodders 2000).

Barrat *et al.* (2002) use Ba/La and Sr/Nd ratios to show that DaG 476 and 489 have been chemically altered by terrestrial weathering. These samples also have very high U compared to Th, which is another characteristic of terrestrial weathering (figure XIV-5).

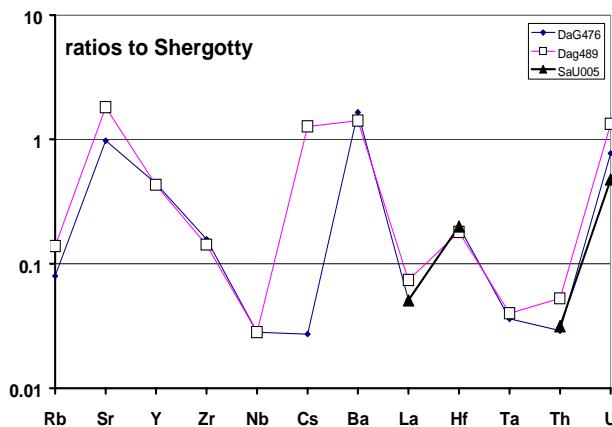


Figure XIV-4: Trace element composition of DaG and SaU samples divided by that of Shergotty (data from dependable sources). Note the depletion in Rb, Nb, Cs, Ta, Th - as well as in LREE.

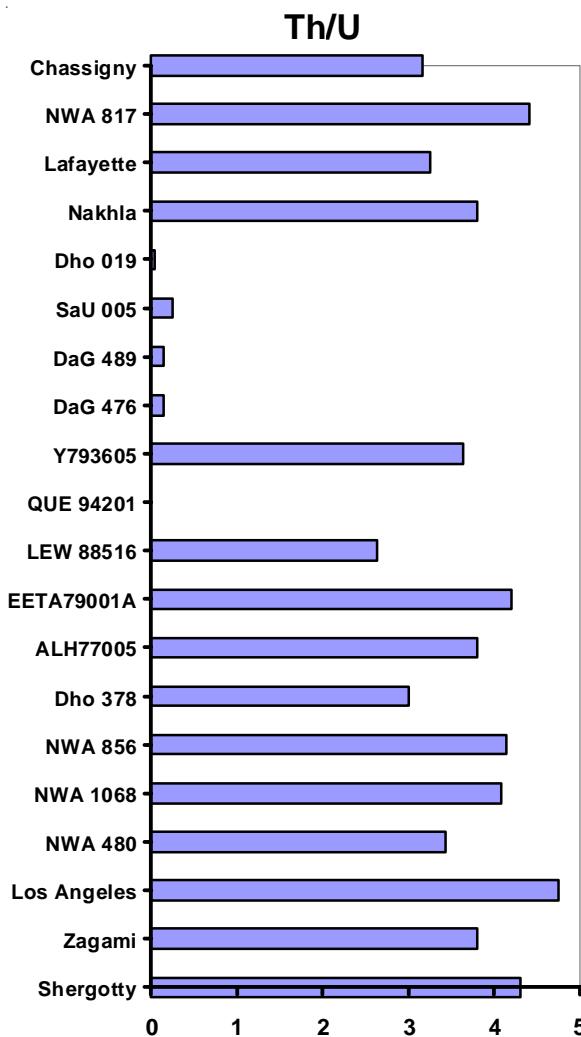


Figure XIV-5: Th/U ratios of Martian meteorites (data from dependable sources).

Radiogenic Isotopes

Borg *et al.* (2000), determined the age of DaG by Sm-Nd to be 474 ± 11 Ma (figure XIV-6) which is significantly younger than the age determined by Jagoutz *et al.* (1999) (703 ± 24 Ma). Borg *et al.* (2000) found that the Rb-Sr systematics could not be used to determine an age, because of the extensive terrestrial weathering effects. Crozaz and Wadhwa (2001) urge caution when using whole rock, or even mineral separates, for isotopic studies, because of the ‘extreme weathering effects’ they observe in samples of DaG.

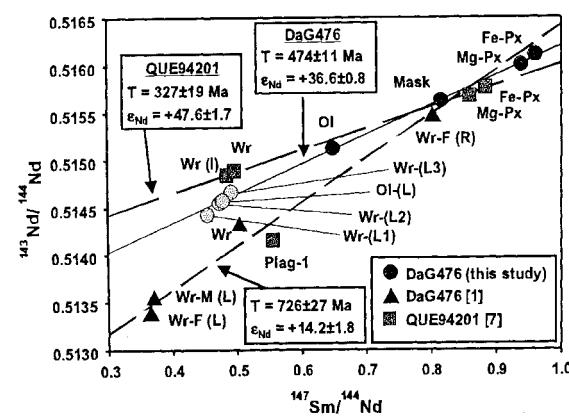


Figure XIV-6: Sm-Nd internal mineral isochron for Dar al Gani 476 (from Borg *et al.* 2000; LPSC XXXI).

Cosmogenic Isotopes and Exposure Ages

Zipfel *et al.* (2000) gave ^{21}Ne exposure age of 1.26 ± 0.09 Ma. Nishiizumi *et al.* (2001) determined the exposure age from ^{21}Ne to be 1.05 ± 0.10 My and the terrestrial age is 60 ± 20 Ka. Park *et al.* (2001) determined a ^{21}Ne exposure age of 0.75 Ma for DaG 489.

Other Isotopes

Nishizumi *et al.* (2001) determined the activity of ^{10}Be , ^{26}Al , ^{36}Cl , ^{41}Ca and ^{14}C for four different fragments of DaG. Garrison and Bogard *et al.* (2001) report measurements of Ar isotopes.

Franchi *et al.* (1999) and Folco *et al.* (2001) report $\Delta^{17}\text{O}$ of $+0.316\text{\textperthousand}$ and $+0.305\text{\textperthousand}$ for DaG 476 and 489 respectively.

Weathering

A study of terrestrial weathering and ‘caliche’ has been done by Dreibus *et al.* (2001). Crozaz and Wadhwa

(2001) find that the olivine and pyroxenes in DaG are enriched in light REE, Ba, Sr and Cs due to terrestrial weathering, and ‘urge caution’ when using whole rock, or mineral separates for isotopic data. Indeed, since these samples were extremely low in trace elements (when they left Mars), they are very sensitive to

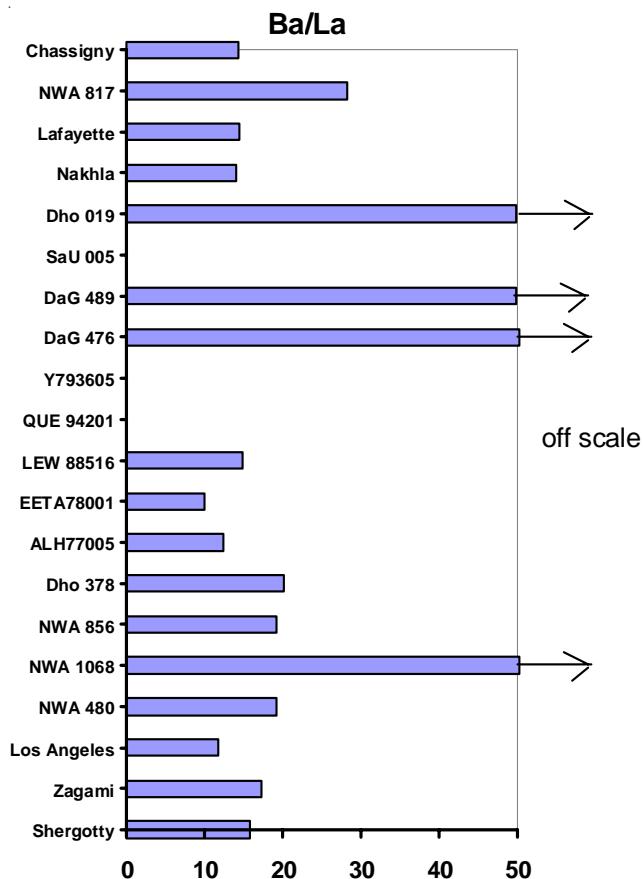


Figure XIV-7: Ba/La ratios for various Martian meteorites. Meteorites found in desert regions often have Ba/La ratios that are off-scale! (data plotted from dependable sources).

contamination by terrestrial U and Ba (figures XIV-5 and XIV-7)!!

Processing

The main mass of these meteorites are owned by the ‘anonymous finders’ (Grossman 1999, 2000). Pictures of DaG 489 and how it was sampled are shown in Folco *et al.* (2000).

Table XIV-1. Chemical composition of Dar al Gani 476.**DaG 489**

reference weight	Zipfel (abs)	Zipfel 2000 66.1 mg.	Zipfel 2000 191.5 mg.	Zipfel 2000 232 mg.	Zipfel 2001 93.7 mg.	Barrat 2001 62.2 mg.	Barrat 2001 138.2 mg.	Folco 2000 1.5 grams
SiO ₂	48.91			45.76	(b)			47.72 (b)
TiO ₂	0.38	(a) 0.42	(a) 0.39	(b) 0.33	(e) 0.41	(e) 0.38	(e) 0.35	(b)
Al ₂ O ₃	4.42	(a) 4.35	(a) 4.37	(b) 4.53	(e) 4.96	(e) 4.17	(e) 4.19	(b)
FeO	17.17	16.1 (a)	16.1 (a)	16.06 (b)	16.12 (e)	15.39 (e)	16.43 (e)	16.52 (b)
MnO	0.43	(a) 0.42	(a) 0.45	(b) 0.47	(e) 0.47	(e) 0.48	(e) 0.394	(b)
CaO	5.84	8.68 (a)	7.25 (a)	7.66 (b)	7.28 (e)	7.48 (e)	7.57 (e)	7.83 (b)
MgO	20.75	18.6 (a)	19 (a)	19.41 (b)	19.18 (e)	18.12 (e)	19.24 (e)	19.36 (b)
Na ₂ O	0.5	(a) 0.51	(a)		0.71 (e)	0.7 (e)	0.66 (e)	0.55 (c)
K ₂ O	0.05	(a) 0.04	(a)	0.038 (b)				0.033 (c)
P ₂ O ₅				0.32 (b)				0.49 (b)
sum				94.458				97.437
Li ppm								2.6 (d)
C	4700		4700	(f)				
S	2700		2700	(f)				
Cl	<840	(a)						
Sc	29.9	30.6 (a)	29.9 (a)		32 (d)	34 (d)	29 (d)	(d)
V	182	(a) 186	(a)					171 (d)
Cr	5704							4603 (d)
Co	51.1	52.1 (a)	51.1 (a)		49 (d)	46.5 (d)	51.3 (d)	50 (d)
Ni	300	220 (a)	300 (a)		225 (d)	211 (d)	230 (d)	214 (d)
Cu	<80	(a) <90	(a)		8.5 (d)	8.4 (d)	8.3 (d)	6.7 (d)
Zn	66	51 (a)	66 (a)		44 (d)	61 (d)	49 (d)	49 (d)
Ga	8.7	8.5 (a)	8.7 (a)		8.56 (d)	9.08 (d)	7.97 (d)	
Ge								
As	0.51	(a) 0.24	(a)					
Se	<0.9	(a) 0.4	(a)					
Br	0.72	(a) 1.29	(a)	Borg et al.				
Rb	<4	(a) <3	(a)		1.19 (d)	0.66 (d)	0.51 (d)	0.89 (d)
Sr					70 (d)	47 (d)	47 (d)	87 (d)
Y					7.99 (d)	9.2 (d)	8.37 (d)	8.2 (d)
Zr					9.19 (d)	10.1 (d)	9.02 (d)	8.1 (d)
Nb					0.18 (d)	0.16 (d)	0.13 (d)	0.13 (d)
Mo								0.18 (d)
Sb ppb	<30	(a) <30	(a)					
Cs ppm					0.02 (d)	0.013 (d)	0.012 (d)	0.56 (d)
Ba	84	(a) 73	(a)		36.4 (d)	74.3 (d)	55.7 (d)	48 (d)
La	0.09	(a) 0.12	(a)		0.157 (d)	0.121 (d)	0.111 (d)	0.16 (d)
Ce					0.372 (d)	0.327 (d)	0.286 (d)	0.4 (d)
Pr					0.06 (d)	0.062 (d)	0.049 (d)	0.11 (d)
Nd		<0.5 (a)	(a)		0.42 (d)	0.494 (d)	0.422 (d)	0.56 (d)
Sm	0.31	(a) 0.39	(a)		0.304 (d)	0.391 (d)	0.352 (d)	0.38 (d)
Eu	0.17	(a) 0.17	(a)		0.186 (d)	0.201 (d)	0.179 (d)	0.22 (d)
Gd					0.751 (d)	0.067 (d)	0.922 (d)	1 (d)
Tb	0.16	(a) 0.2	(a)		0.163 (d)	0.227 (d)	0.204 (d)	0.2 (d)
Dy	1.6	(a) 1.3	(a)		1.23 (d)	1.59 (d)	1.46 (d)	1.38 (d)
Ho	0.2	(a) 0.3	(a)		0.282 (d)	0.352 (d)	0.328 (d)	0.3 (d)
Er					0.798 (d)	1 (d)	0.932 (d)	0.87 (d)
Tm								0.13 (d)
Yb	0.73	(a) 0.81	(a)		0.746 (d)	0.942 (d)	0.83 (d)	0.79 (d)
Lu	0.12	(a) 0.13	(a)		0.115 (d)	0.142 (d)	0.122 (d)	0.12 (d)
Hf	0.32	(a) 0.39	(a)		0.34 (d)	0.42 (d)	0.4 (d)	0.36 (d)
Ta	<0.03	(a) <0.02	(a)		0.011 (d)	0.012 (d)	0.009 (d)	0.01 (d)
W ppb	<200	(a) <300	(a)	Brandon 2000	40 (d)	20 (d)	20 (d)	240 (d)
Re ppb					0.505 (d)	0.633 (d)		
Os ppb					1.546 (d)	2.008 (d)		
Ir ppb	<6	(a) <2.5	(a)					
Au ppb	<1	(a) 2.1	(a)					
Tl ppb								0.02 (d)
Th ppm	<0.1	(a) <0.08	(a)		0.025 (d)	0.016 (d)	0.011 (d)	0.02 (d)
U ppm	0.12	(a) 0.09	(a)		0.107 (d)	0.063 (d)	0.081 (d)	0.14 (d)

technique (a) INAA, (b) XRF, (c) AA, (d) ICP-MS, (e) ICP-AES, (f) C, S analysers